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Yata et al.

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(54) **DISPLAY AND ELECTRONIC UNIT**

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G02F 1/1335 (2006.01)
G02B 5/02 (2006.01)

(52) **U.S. Cl.**
CPC ***G02F 1/133504*** (2013.01); ***G02B 5/0257*** (2013.01); ***G02B 5/0278*** (2013.01); ***G02F 1/133615*** (2013.01); *G02F 1/133553* (2013.01); *G02F 2001/133616* (2013.01); *G02F 2001/133626* (2013.01); *G02F 2203/02* (2013.01)

(58) **Field of Classification Search**
CPC G02B 6/0038; G02B 6/006; G02B 6/0021; G02B 6/0028; G02B 6/0053; G02B 6/0031; B60Q 1/2607; F21V 13/04; F21V 5/04; F21S 48/1233; F21S 48/2212; F21S 48/1208; F21S 48/2118
USPC 362/602, 603, 607, 520, 521, 308
See application file for complete search history.

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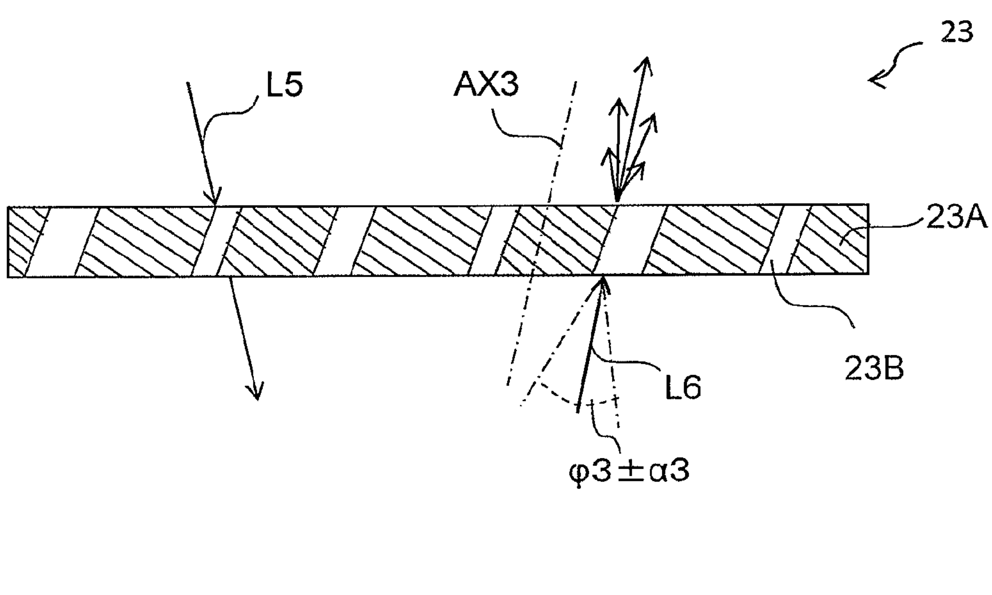
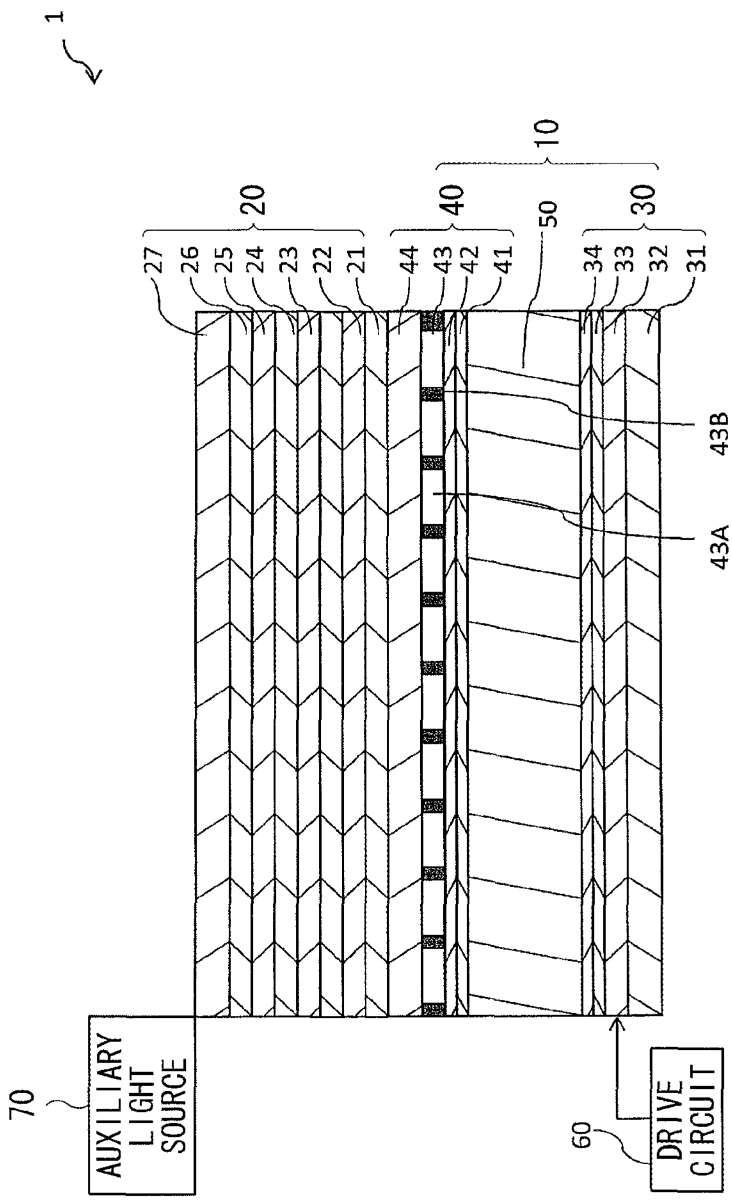
(57) **ABSTRACT**

A display includes: a reflective or semi-transmissive display panel; a light-scattering layer disposed on a top surface of the display panel; and an auxiliary light source. The light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range. The light-scattering layer has a first scattering central axis and a second scattering central axis. The first angle range and a third angle range overlap each other in an angle sub-range not including a first specific angle and an incident-plane symmetrical angle symmetrical to a second specific angle. The auxiliary light source allows light therefrom incident from a side closer to the auxiliary light source or from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

13 Claims, 21 Drawing Sheets

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AUXILIARY LIGHT SOURCE
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DRIVE CIRCUIT

FIG. 1

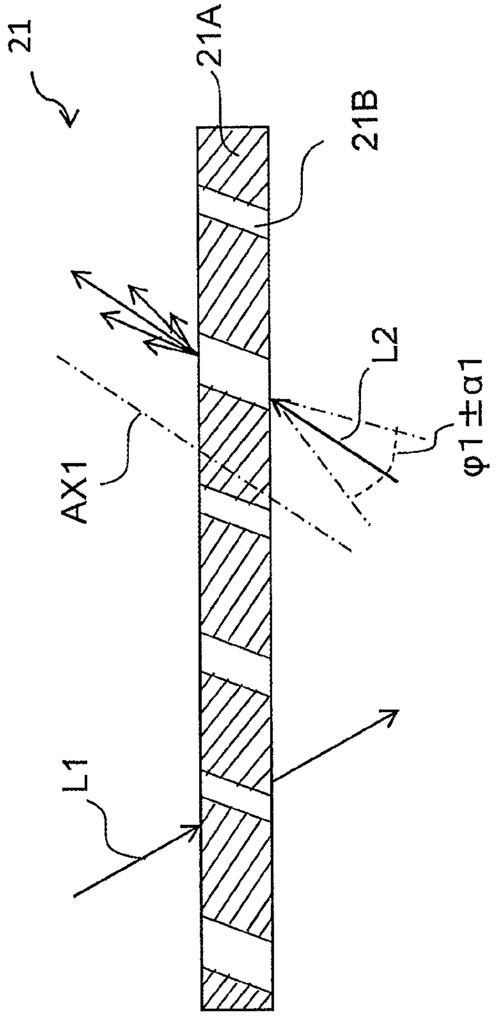


FIG. 2

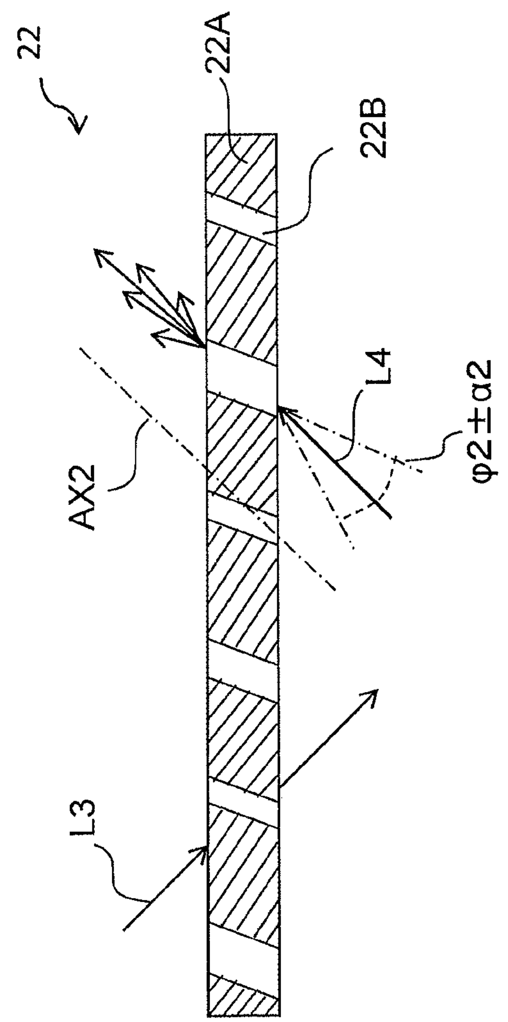
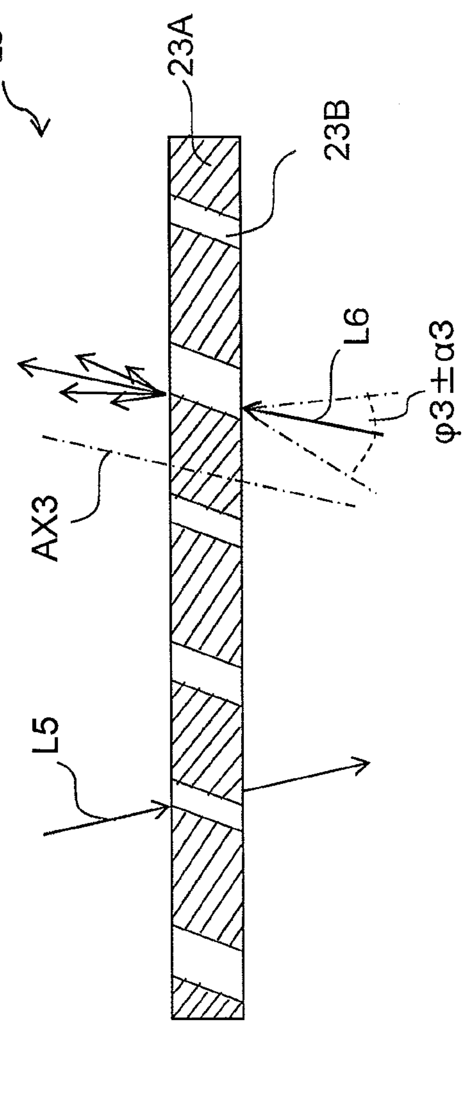


FIG. 3



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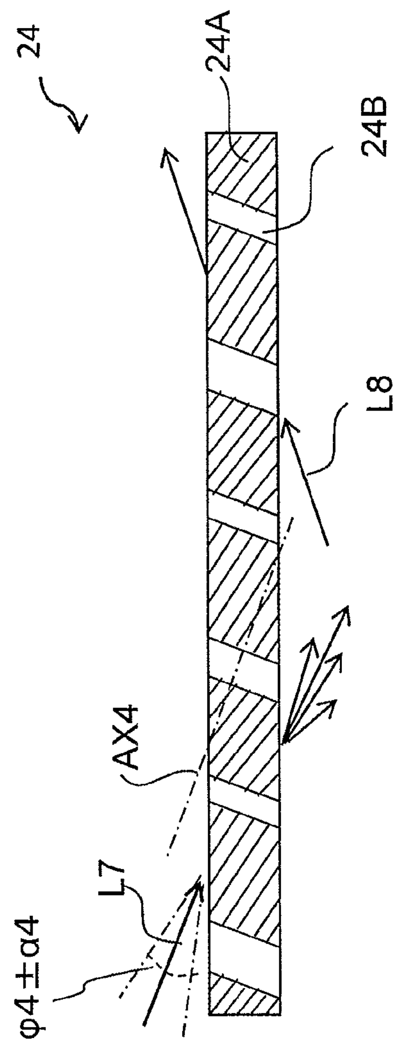

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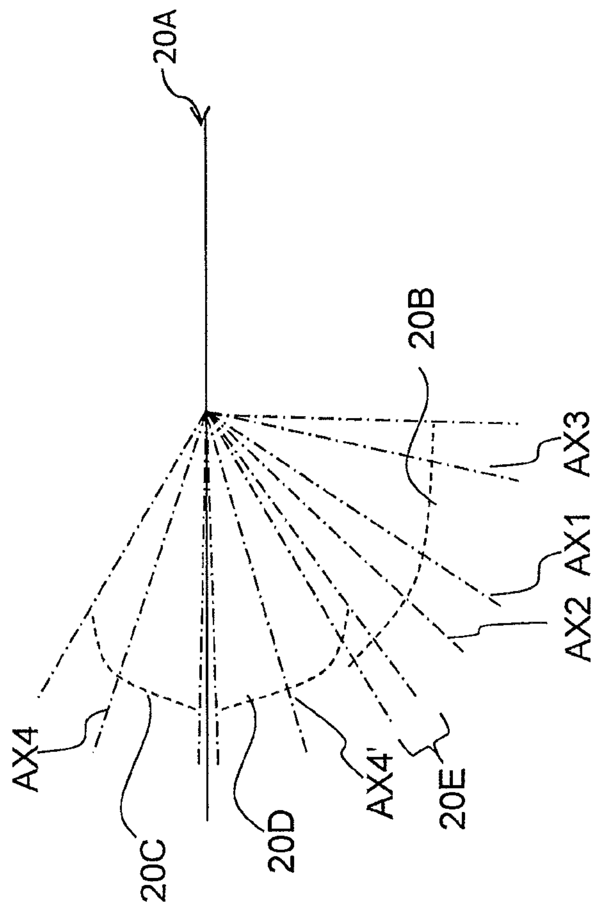

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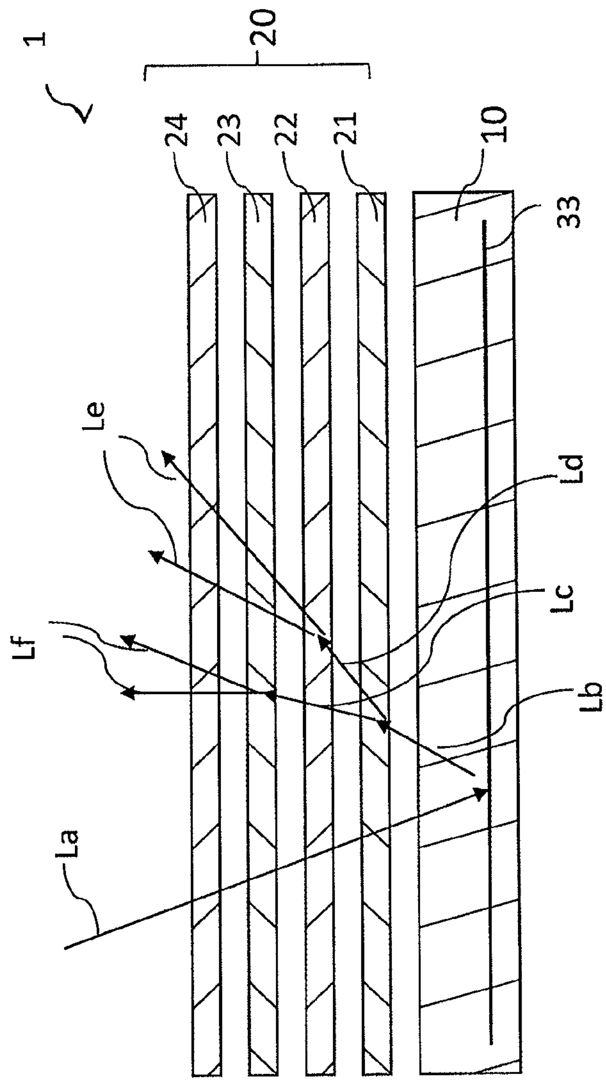

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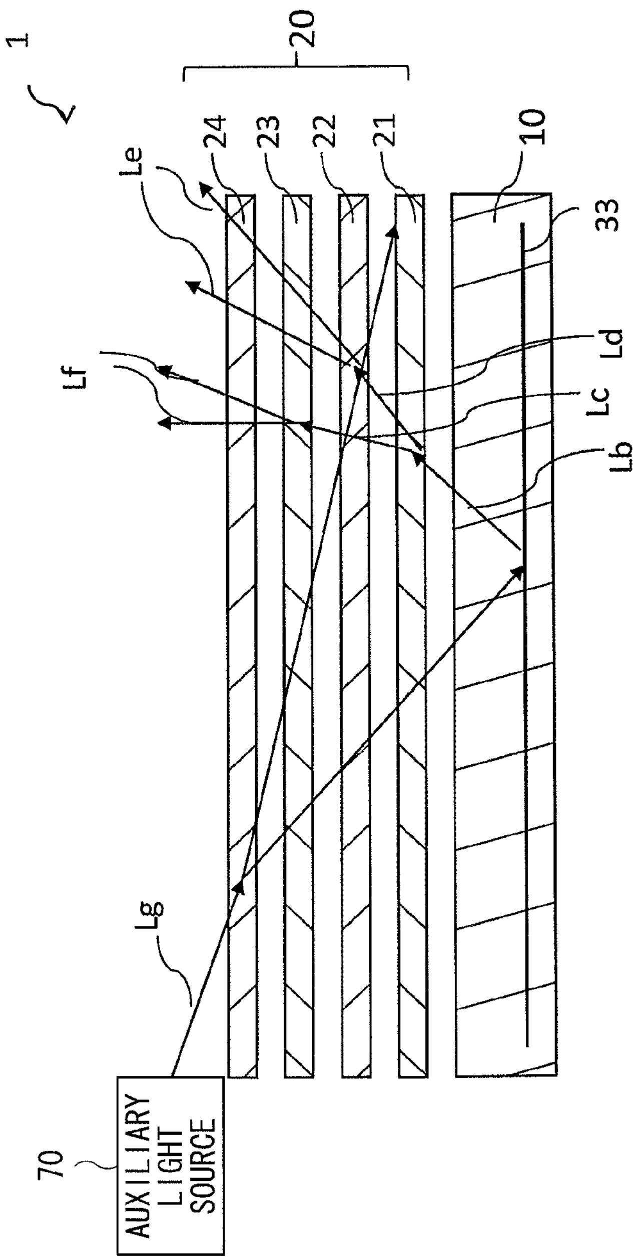
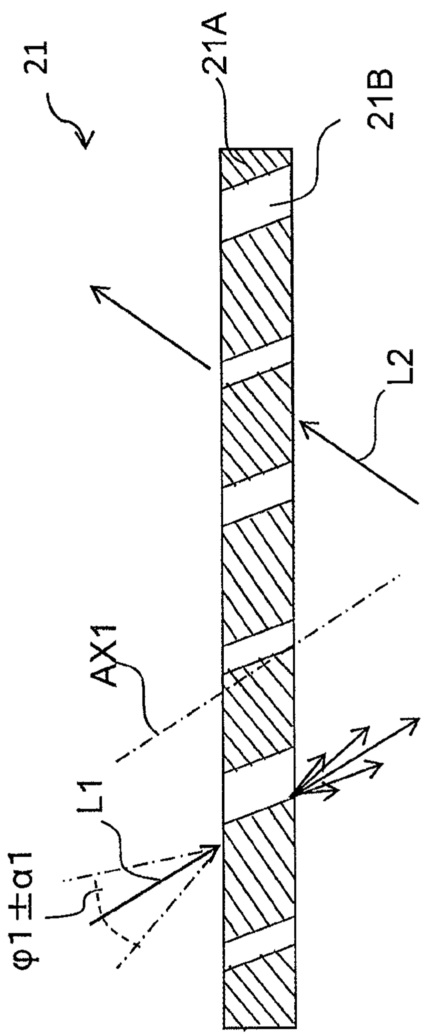


FIG. 8



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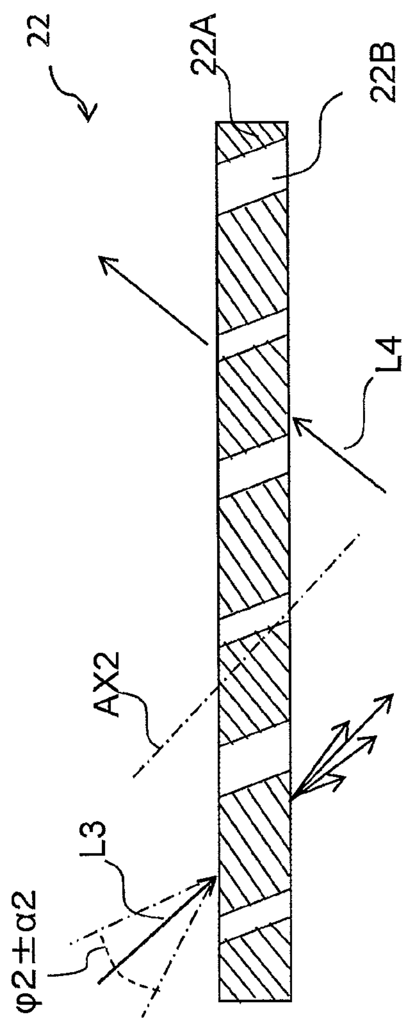
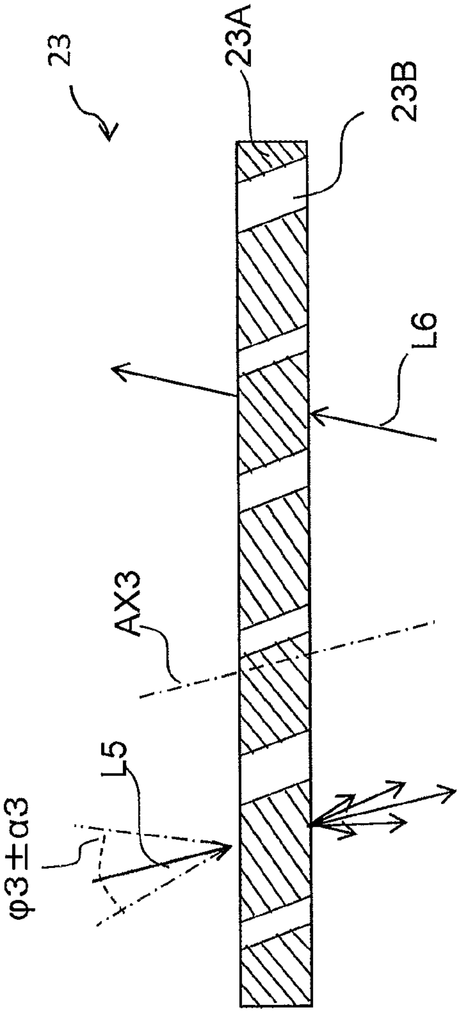


FIG. 10



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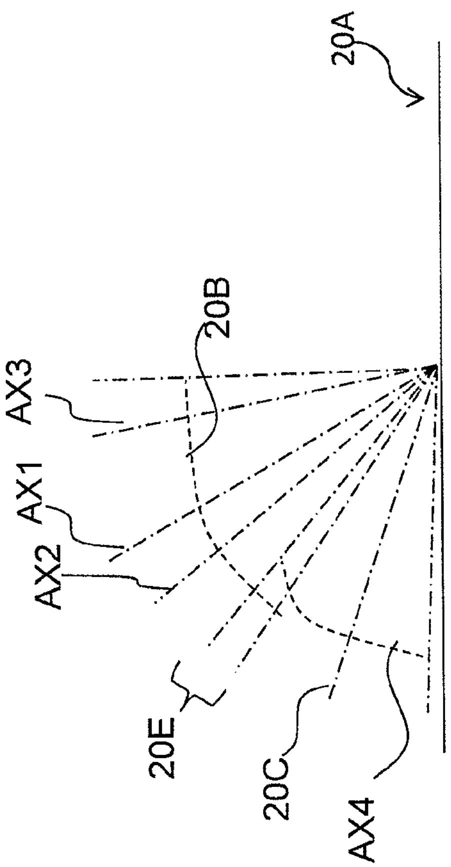
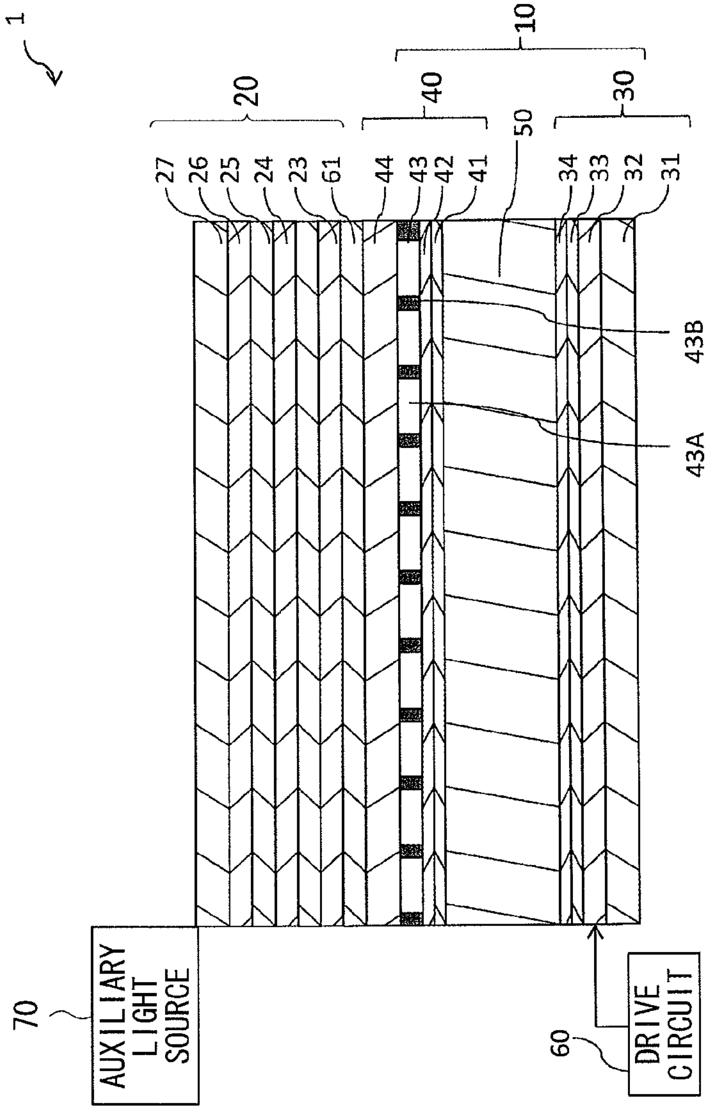


FIG. 12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AUXILIARY LIGHT SOURCE
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DRIVE CIRCUIT
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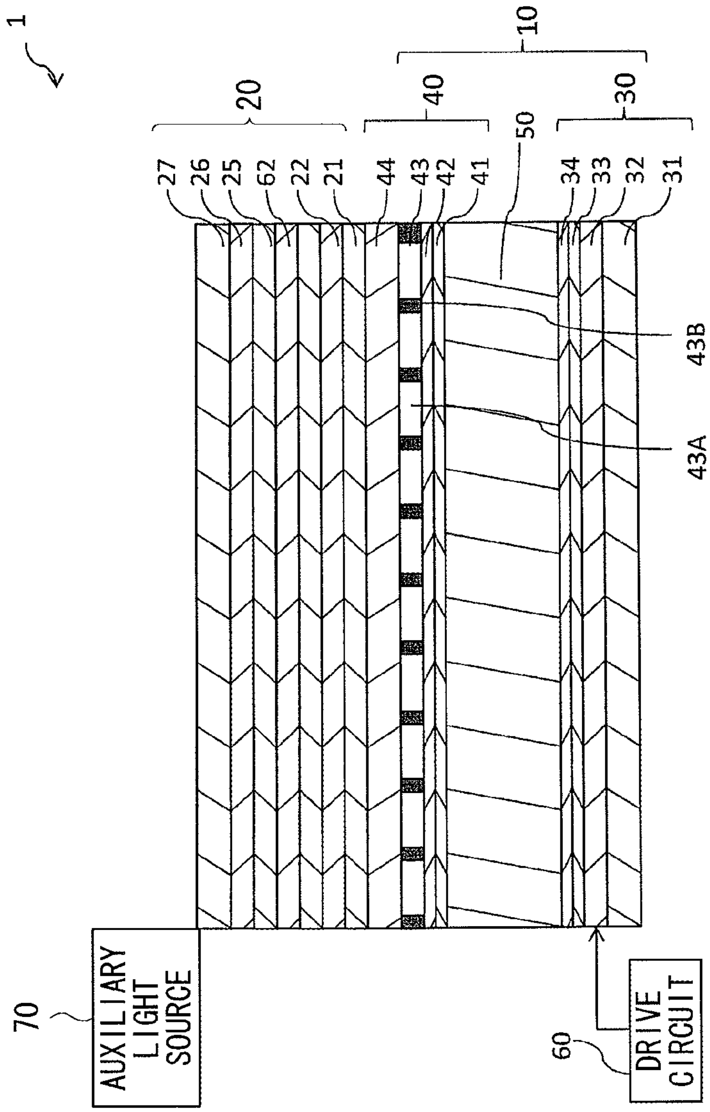
FIG. 13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AUXILIARY LIGHT SOURCE
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FIG. 14

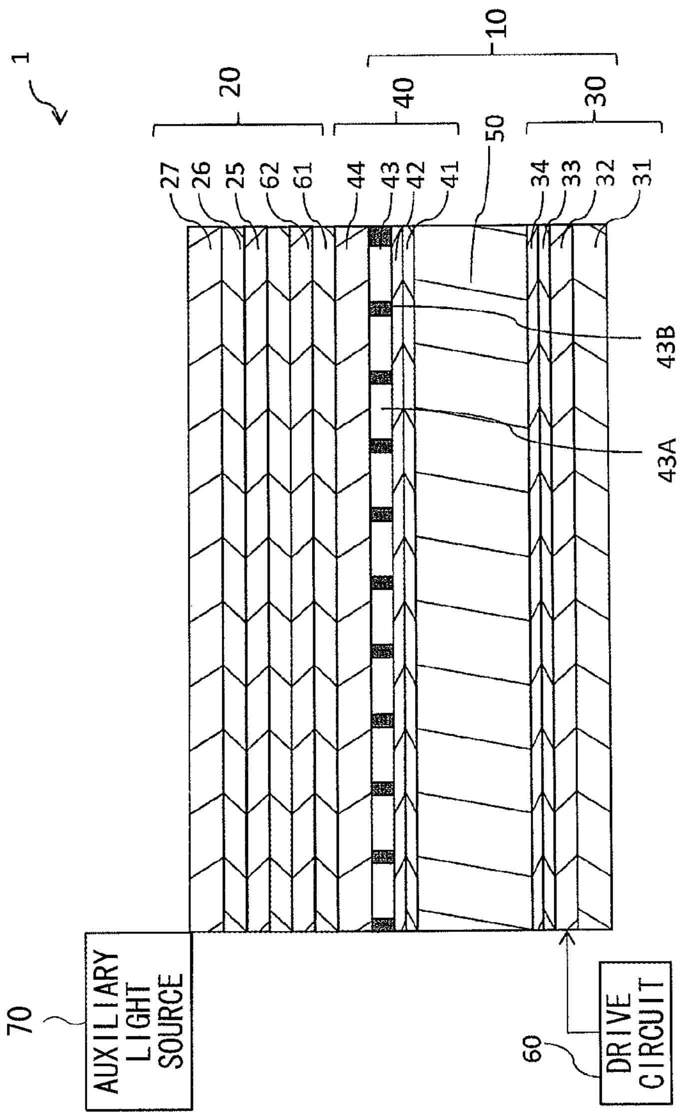
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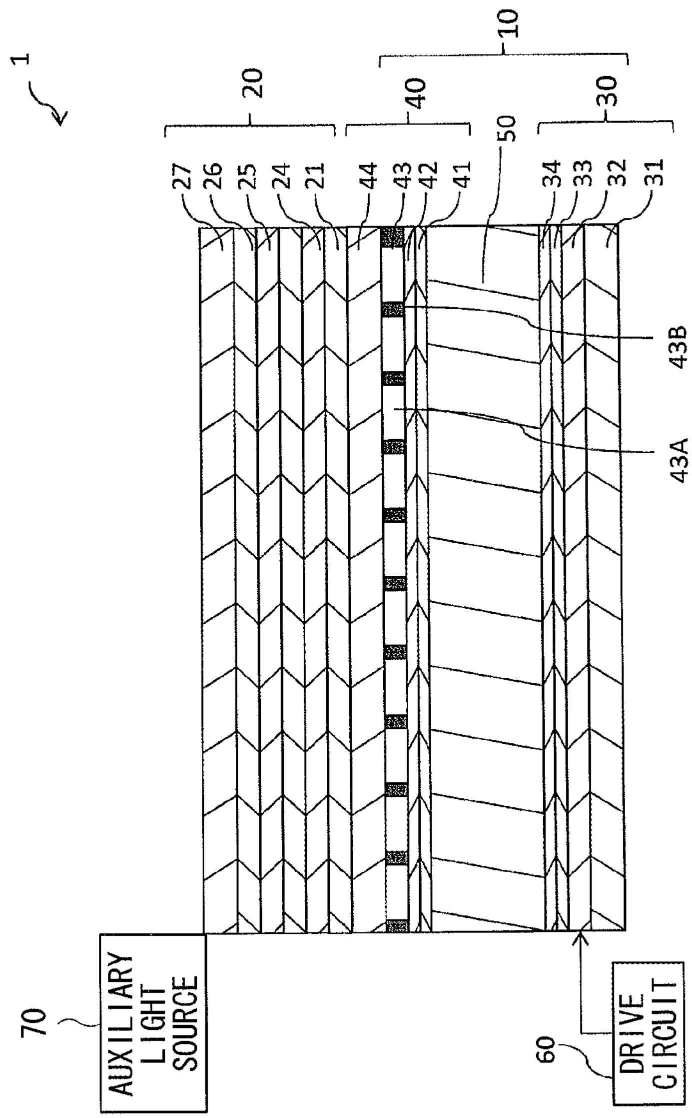
FIG. 15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AUXILIARY LIGHT SOURCE
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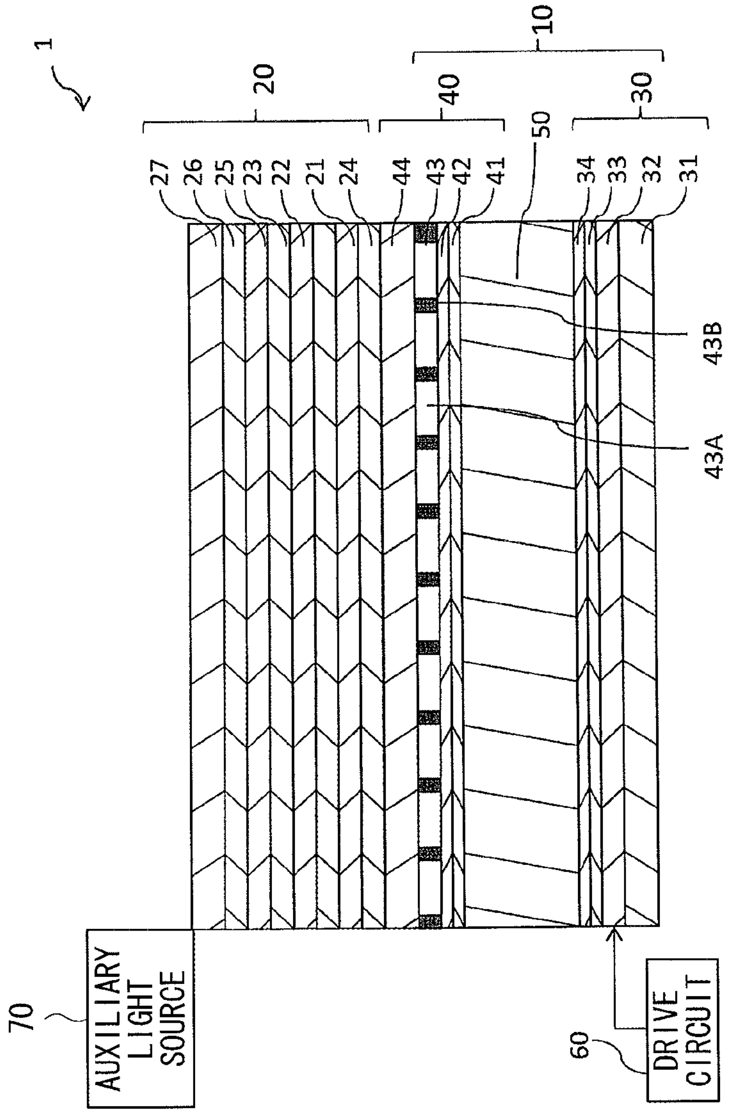
DRIVE CIRCUIT

FIG. 16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AUXILIARY LIGHT SOURCE
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DRIVE CIRCUIT

FIG. 17

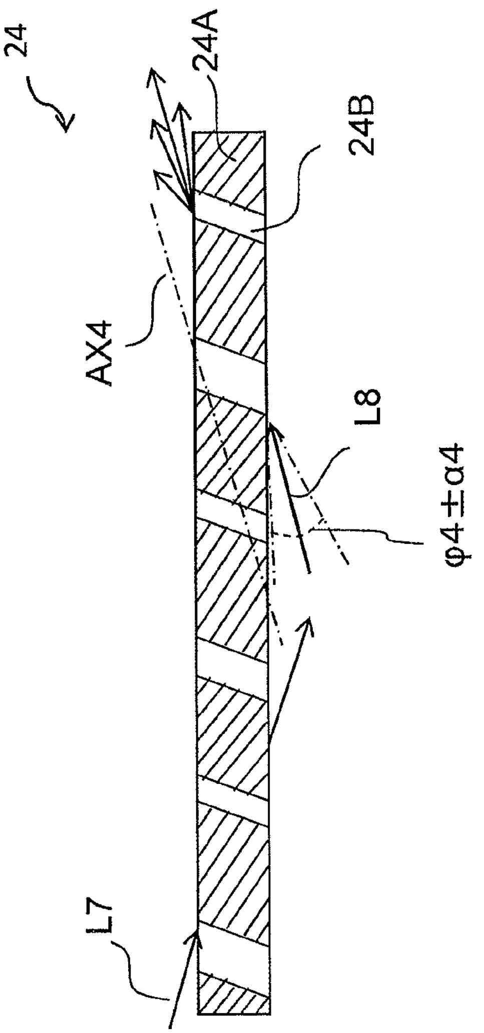

FIG. 18

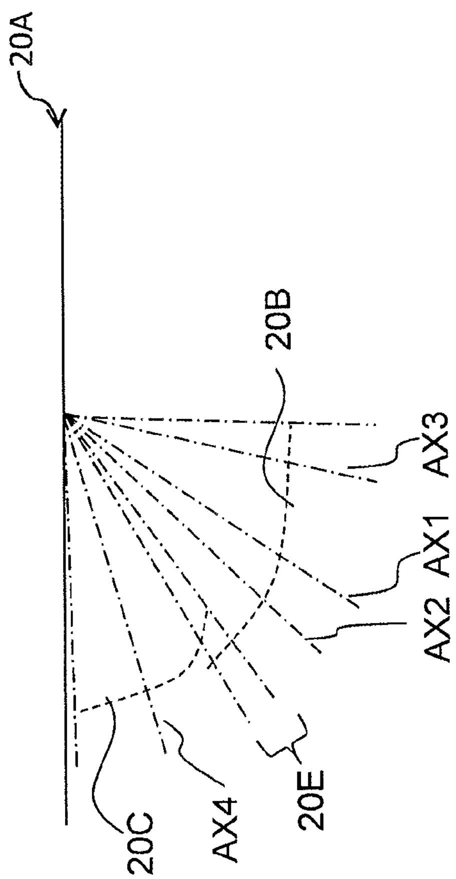

FIG. 19

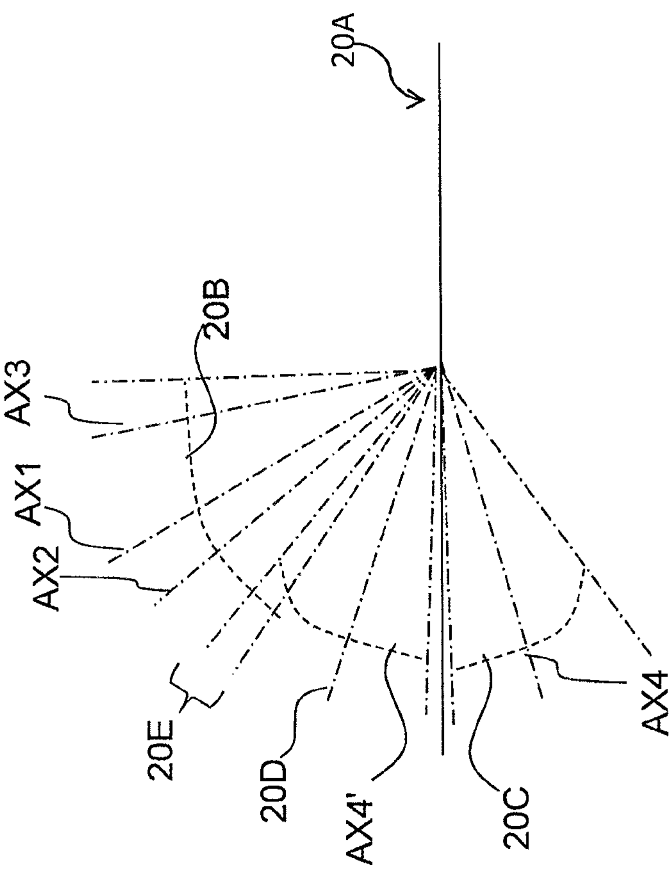

FIG. 20

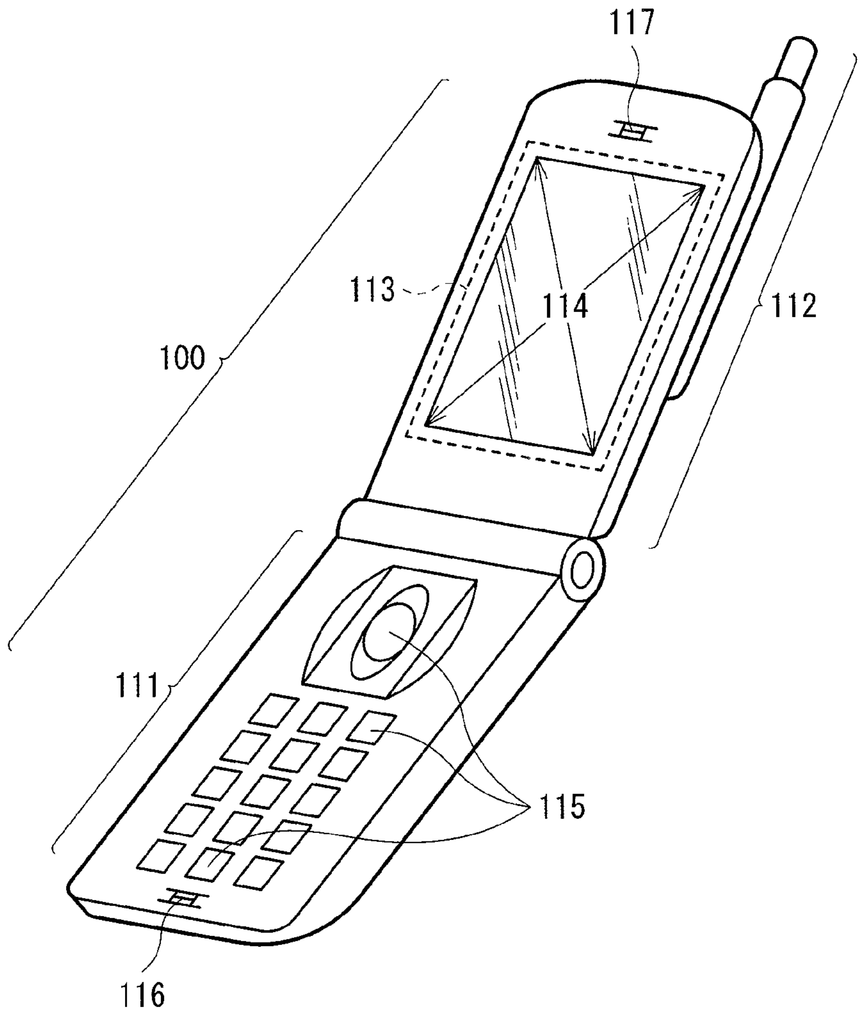

FIG. 21

DISPLAY AND ELECTRONIC UNIT

BACKGROUND

The present technology relates to a reflective display or a semi-transmissive display having both a reflection section and a transmission section, and an electronic unit including the same.

In recent years, displays for mobile units such as cellular phones and electronic papers have been in increasing demand, and attention has been given to reflective displays. The reflective displays perform display by reflecting externally incident light (ambient light) by a reflective plate, and do not need a backlight. Consequently, power consumption is reduced by power for the backlight; therefore, a mobile unit using the reflective display is allowed to be driven for a longer time than a mobile unit using a transmissive display. Moreover, as the backlight is not necessary, the weight and size of the display are allowed to be reduced accordingly.

In the reflective display, to perform display with use of external light, it is necessary to include a layer having a scattering function in the display. For example, in Japanese Patent No. 2771392, there is disclosed a method of providing a scattering function to a reflective electrode by forming projections and recessions on the reflective electrode. Moreover, Japanese patent No. 3629991 and Japanese Unexamined Patent Application Publication Nos. H11-326895, H11-7007, H11-326884, and H11-109348 disclose a method of providing a scattering film on a top surface of a glass substrate, instead of providing projections and recessions on the reflective electrode.

SUMMARY

In the reflective display, viewability in a dark site is low; therefore, an auxiliary light source is preferably included in the reflective display. However, for example, in the case where a front scattering film having anisotropy in a scattering direction as the above-described scattering film is included in the reflective display, there is an issue that the position of the auxiliary light source is limited.

It is desirable to provide a display capable of having flexibility in placement of an auxiliary light source and an electronic unit including the display.

According to an embodiment of the technology, there is provided a first display including: a reflective or semi-transmissive display panel; a light-scattering layer disposed on a top surface of the display panel; and an auxiliary light source supplying light to the display panel through the light-scattering layer. The light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges. The light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range. The first angle range and a third angle range which is an incident-plane symmetrical angle range symmetrical to the second angle range overlap each other in an angle sub-range not including the first specific angle and an incident-plane symmetrical angle symmetrical to the second specific angle. The auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a

side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

Here, the "incident-plane symmetrical angle range" means an angle range symmetrical to the second angle range with respect to an incident plane where light enters from a specific direction at an angle within the second angle range. The "incident-plane-symmetrical angle" means an angle symmetrical to the second angle with respect to the incident plane where light enters from a specific direction at an angle within the second angle range.

According to an embodiment of the technology, there is provided a first electronic unit including a display, the display including: a reflective or semi-transmissive display panel; a light-scattering layer disposed on a top surface of the display panel; and an auxiliary light source supplying light to the display panel through the light-scattering layer. The light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges. The light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range. The first angle range and a third angle range which is an incident-plane symmetrical angle range symmetrical to the second angle range overlap each other in an angle sub-range not including the first specific angle and an incident-plane symmetrical angle symmetrical to the second specific angle. The auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

In the first display and the first electronic unit according to the embodiment of the technology, the second angle range is provided separately from the first angle range. Moreover, the first angle range and the third angle range which is an incident-plane-symmetrical angle range symmetrical to the second angle range overlap each other in an angle sub-range not including the first specific angle and the incident-plane symmetrical angle symmetrical to the second specific angle. Here, when the second angle range is used as a scattering range for using light from the auxiliary light source to display an image, and the first angle range is used as a scattering range for using environmental light to display an image, it is not necessary to place the auxiliary light source to allow light to mainly enter the first angle range (except for the third angle range).

According to an embodiment of the technology, there is provided a second display including: a reflective or semi-transmissive display panel; a light-scattering layer disposed on a top surface of the display panel; and an auxiliary light source supplying light to the display panel through the light-scattering layer. The light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges. The light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range. The first angle range and the second angle range overlap each other in an angle sub-range not including the first specific angle and the second specific angle. The auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

According to an embodiment of the technology, there is provided a second electronic unit including a display, the display including: a reflective or semi-transmissive display panel; a light-scattering layer disposed on a top surface of the display panel; and an auxiliary light source supplying light to the display panel through the light-scattering layer. The light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges. The light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range. The first angle range and the second angle range overlap each other in an angle sub-range not including the first specific angle and the second specific angle. The auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

In the second display and the second electronic unit according to the embodiment of the technology, the second angle range is provided separately from the first angle range. Moreover, the first angle range and the second angle range overlap each other in an angle sub-range not including the first specific angle and the second specific angle. Here, when the second angle range is used as a scattering range for using light from the auxiliary light source to display an image, and the first angle range is used as a scattering range for using environmental light to display an image, it is not necessary to place the auxiliary light source to allow light to mainly enter the first angle range (except for the second angle range).

In the first and second displays and the first and second electronic units, it is not necessary to place the auxiliary light source to allow light to mainly enter the first angle range (except for the second angle range and the third angle range); therefore, flexibility in placement of the auxiliary light source is allowed to be provided.

It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the technology as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and, together with the specification, serve to explain the principles of the technology.

FIG. **1** is a sectional view illustrating an example of a configuration of a display according to an embodiment of the technology.

FIG. **2** is a diagram illustrating an example of a configuration and a function of a lowermost layer in three light-scattering layers for environmental light in FIG. **1**.

FIG. **3** is a diagram illustrating an example of a configuration and a function of a middle layer in the three light-scattering layers for environmental light in FIG. **1**.

FIG. **4** is a diagram illustrating an example of a configuration and a function of an uppermost layer in the three light-scattering layers for environmental light in FIG. **1**.

FIG. **5** is a diagram illustrating an example of a configuration and a function of a light-scattering layer for auxiliary light source in FIG. **1**.

FIG. **6** is a diagram illustrating an example of a relationship between scattering ranges of the respective light-scattering layers in FIG. **1**.

FIG. **7** is a conceptual diagram illustrating an example of image display with use of environmental light in the display in FIG. **1**.

FIG. **8** is a conceptual diagram illustrating an example of image display with use of light from the auxiliary light source in the display in FIG. **1**.

FIG. **9** is a diagram illustrating another example of the configuration and the function of the lowermost layer in the three light-scattering layers for environmental light in FIG. **1**.

FIG. **10** is a diagram illustrating another example of the configuration and the function of the middle layer in the three light-scattering layers for environmental light in FIG. **1**.

FIG. **11** is a diagram illustrating another example of the configuration and the function of the uppermost layer in the three light-scattering layers for environmental light in FIG. **1**.

FIG. **12** is a diagram illustrating an example of a relationship between scattering ranges of the respective light-scattering layers in FIG. **5** and FIGS. **9** to **11**.

FIG. **13** is a sectional view illustrating a first modification of the configuration of the display in FIG. **1**.

FIG. **14** is a sectional view illustrating a second modification of the configuration of the display in FIG. **1**.

FIG. **15** is a sectional view illustrating a third modification of the configuration of the display in FIG. **1**.

FIG. **16** is a sectional view illustrating a fourth modification of the configuration of the display in FIG. **1**.

FIG. **17** is a sectional view illustrating a fifth modification of the configuration of the display in FIG. **1**.

FIG. **18** is a diagram illustrating another example of the configuration and the function of the light-scattering layer for auxiliary light source in FIG. **1**.

FIG. **19** is a diagram illustrating an example of a relationship between scattering ranges of the respective light-scattering layers in FIG. **18** and FIGS. **3** to **5**.

FIG. **20** is a diagram illustrating an example of a relationship between scattering ranges of the respective light-scattering layers in FIGS. **18** and FIGS. **9** to **11**.

FIG. **21** is a perspective view illustrating an example of a configuration of an electronic unit according to an application example.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the technology will be described in detail below referring to the accompanying drawings. It is to be noted that description will be given in the following order.

1. Embodiment (display)
2. Modifications (display)
3. Application Example (electronic unit)

1. Embodiment

Configuration

FIG. **1** illustrates an example of a sectional configuration of a display **1** according to an embodiment of the technology. It is to be noted that FIG. **1** is a schematic illustration, and dimensions and shapes in the illustration are not necessarily the same as actual dimensions and shapes. For example, as illustrated in FIG. **1**, the display **1** includes a liquid crystal display panel **10**, an optical laminate **20** disposed on a top surface of the liquid crystal display panel **10**, a drive circuit **60** driving the liquid crystal display panel **10**, and an auxiliary light source **70**. In the display **1**, a top surface of the optical laminate **20** is an image display surface, and a light source such as a backlight is not disposed behind the liquid crystal display panel **10**. It is to be noted that the display **1** corresponds to a specific example of "display" in the technology, and the liquid crystal display panel **10** corresponds to a specific example of "display panel" in the technology. Moreover, the auxiliary light source **70** corresponds to a specific example of "auxiliary light source" in the technology.

Liquid Crystal Display Panel 10

The liquid crystal display panel **10** is a reflective or a semi-transmissive liquid crystal panel. For example, as illustrated in FIG. **1**, the liquid crystal display panel **10** includes a lower substrate **30**, an upper substrate **40**, and a liquid crystal layer **50** sandwiched between the lower substrate **30** and the upper substrate **40**.

Liquid Crystal Layer 50

The liquid crystal layer **50** is made of, for example, a nematic liquid crystal. The liquid crystal layer **50** is driven based on an image signal, and has a modulation function of allowing light incident to the liquid crystal layer **50** to pass therethrough or blocking the light in each pixel by application of a voltage based on the image signal. It is to be noted that the gray scale of each pixel is adjusted by varying the light transmission level of the liquid crystal.

Lower Substrate 30

For example, as illustrated in FIG. **1**, the lower substrate **30** includes a driver board **31** on which a TFT (Thin Film Transistor) or the like is formed, an insulating layer **32** covering the TFT or the like, a reflective electrode layer **33** electrically connected to the TFT or the like, and an alignment film **34** formed on a top surface of the reflective electrode layer **33**.

The driver board **31** includes, for example, a pixel circuit including a TFT, a capacitive device, or the like on a transparent substrate made of, for example, a glass substrate. The transparent substrate may be made of a material other than the glass substrate, for example, a translucent resin substrate, quartz, or a silicon substrate.

The reflective electrode layer **33** drives the liquid crystal layer **50** with a transparent electrode layer **42** (which will be described later) disposed in the upper substrate **40**, and is configured of, for example, a plurality of pixel electrodes two-dimensionally arranged in a plane. When a voltage is applied to the pixel electrodes and the transparent electrode layer **42**, an electrical field corresponding to a potential difference between the pixel electrodes and transparent electrode layer **42** is generated between the pixel electrodes and the transparent electrode layer **42**, and the liquid crystal layer **50** is driven according to the magnitude of the electrical field. A portion corresponding to a portion where each pixel electrode and the transparent electrode layer **42** face each other in the display **1** is a minimum unit where the liquid crystal layer **50** is allowed to be partially driven by a voltage applied between the pixel electrode and the transparent electrode layer **42**. This minimum unit corresponds to a pixel of the liquid crystal display panel **10**. Moreover, the reflective electrode layer **33** functions as a reflective layer reflecting environmental light incident thereto through the liquid crystal layer **50** toward the liquid crystal layer **50**. The reflective electrode layer **33** is made of a conductive material reflecting visible light, for example, a metal material such as Ag. A surface of the reflective electrode layer **33** is, for example, a mirror-finished surface.

The alignment film **34** aligns liquid crystal molecules in the liquid crystal layer **50** in a predetermined direction, and is directly in contact with the liquid crystal layer **50**. The alignment film **34** is made of a polymer material such as polyimide, and is formed by performing a rubbing process on coated polyimide or the like.

Upper Substrate 40

For example, as illustrated in FIG. **1**, the upper substrate **40** includes an alignment film **41**, a transparent electrode layer **42**, a color filter (CF) layer **43**, and a transparent substrate **44** in this order from a side closer to the liquid crystal layer **50**.

The alignment film **41** aligns liquid crystal molecules in the liquid crystal layer **50** in a predetermined direction, and is directly in contact with the liquid crystal layer **50**. The alignment film **41** is made of a polymer material such as polyimide, and is formed by performing a rubbing process on coated polyimide or the like.

The transparent electrode layer **42** is disposed to face respective pixel electrodes, and is, for example, a sheet-like electrode formed on an entire plane. As the transparent electrode layer **42** is disposed to face respective pixel electrodes, the transparent electrode layer **42** functions as a common electrode for pixels. The transparent electrode layer **42** is made of a conductive material transparent to environmental light, for example, ITO (Indium Tin Oxide).

The CF layer **43** includes a color filter **43**A in a region facing the pixel electrode and a light-shielding film **43**B in a region not facing the pixel electrode. In the color filter **43**A, color filters separating light having passed through the liquid crystal layer **50** into, for example, three primary colors of red, green, and blue, respectively, are arranged corresponding to pixels, respectively. The light-shielding film **43**B has, for example, a function of absorbing visible light. The light-shielding film **43**B is formed between pixels. The transparent substrate **44** is configured of a substrate transparent to environmental light, for example, a glass substrate.

Optical Laminate 20

For example, as illustrated in FIG. **1**, the optical laminate **20** includes light-scattering layers **21** to **24**, a ¼λ plate **25**, a ½λ plate **26**, and a polarizing plate **27** in this order from a side closer to the liquid crystal layer **50** on a top surface of the transparent substrate **44**. The light-scattering layers **21** to **24**, the ¼λ plate **25**, the ½λ plate **26**, and the polarizing plate **27** each are bonded to an adjacent layer with a sticking layer or an adhesive layer.

The light-scattering layers **21** to **23** are light-scattering layers for environmental light, and the light-scattering layer **24** is a light-scattering layer for the auxiliary light source **70**. The light-scattering layers **21** to **24** are anisotropic front scattering layers which relatively strongly scatter light incident from a specific direction within a specific angle range and relatively weakly scatter light incident within an angle range other than the specific angle range. The above-described specific direction is, for example, a direction parallel to a main perspective direction. Here, the main perspective direction corresponds to a direction where a user of the display **1** views an image display surface when the user uses the display **1**, and when the image display surface has a square shape, the main perspective direction corresponds to a direction orthogonal to a side closest to the user of the image display surface. In the light-scattering layers **21** to **24**, a scattering distribution of scattered light has, for example, isotropy. It is to be noted that, in the light-scattering layers **21** to **24**, the scattering distribution of the scattered light may have anisotropy extending in the main perspective direction.

FIGS. **2** to **5** schematically illustrate examples of optical functions of the light-scattering layers **21** to **24** together with examples of sectional configurations of the light-scattering layers **21** to **24**. For example, as illustrated in FIG. **2**, the light-scattering layer **21** is an anisotropic scattering layer which relatively strongly scatters a light component incident from the specific direction within a specific angle range $\phi1\pm\alpha1$ in light L**2** incident from a bottom surface thereof, and relatively weakly scatters other light components (for example, light L**1** in the drawing). The light-scattering layer **21** has a scattering central axis corresponding to a specific angle within the specific angle range $\phi1\pm\alpha1$. For example, as illustrated in FIG. **2**, the light-scattering layer **21** has a scattering central axis AX**1** where scattering of light L**2** peaks when the light L**2** is incident at an incident angle ψ from the bottom surface thereof.

It is to be noted that "incident angle" indicates an angle between an optical axis of light and a normal to a light incident plane. Moreover, "scattering of light L**2** peaks when the light L**2** is incident at an incident angle $\psi1$" means that when the light L**2** is scattered by the light-scattering layer **21** to exit to a top surface of the light-scattering layer **21**, the incident angle of the light L**2** where the scattering range of the scattered light is maximized is $\psi1$. Therefore, the scattering central axis AX**1** indicates an axis extending in a direction intersecting with a normal to the light-scattering layer **21** at the angle $\psi1$. The angle $\psi1$ of the scattering central axis AX**1** is, for example, 30°.

For example, as illustrated in FIG. **3**, the light-scattering layer **22** is an anisotropic scattering layer which relatively strongly scatters a light component incident from the specific direction within a specific angle range $\phi\pm\alpha2$ in light L**4** incident from a bottom surface thereof, and relatively weakly scatters other light components (for example, light L**3** in the drawing). The light-scattering layer **22** has a scattering central axis corresponding to a specific angle within the specific angle range $\phi\pm\alpha2$. For example, as illustrated in FIG. **3**, the light-scattering layer **22** has a scattering central axis AX**2** where scattering of the light L**4** peaks when the light L**4** is incident at an incident angle $\psi2$ from the bottom surface thereof.

It is to be noted that "scattering of the light L**4** peaks when the light L**4** is incident at an incident angle $\psi2$" means that when the light L**4** is scattered by the light-scattering layer **22** to exit to a top surface of the light-scattering layer **22**, the incident angle of the light L**4** where the scattering range of the scattered light is maximized is $\psi2$. Therefore, the scattering central axis AX**2** indicates an axis extending in a direction intersecting with a normal to the light-scattering layer **22** at the angle $\psi2$. The angle $\psi2$ of the scattering central axis AX**2** is, for example, 45°.

For example, as illustrated in FIG. **4**, the light-scattering layer **23** is an anisotropic scattering layer which relatively strongly scatters a light component incident from the specific direction within a specific angle range $\phi3\pm\alpha3$ in light L**6** incident from a bottom surface thereof, and relatively weakly scatters other light components (for example, light L**5** in the drawing). The light-scattering layer **23** has a scattering central axis corresponding to a specific angle within the specific angle range $\phi3\pm\alpha3$. For example, as illustrated in FIG. **4**, the light-scattering layer **23** has a scattering central axis AX**3** where scattering of the light L**6** peaks when the light L**6** is incident at an incident angle $\psi3$ from the bottom surface thereof.

It is to be noted that "scattering of the light L**6** peaks when the light L**6** is incident at an incident angle $\psi3$" means that when the light L**6** is scattered by the light-scattering layer **23** to exit to a top surface of the light-scattering layer **23**, the incident angle of the light L**6** where the scattering range of the scattered light is maximized is $\psi3$. Therefore, the scattering central axis AX**3** indicates an axis extending in a direction intersecting with a normal to the light-scattering layer **23** at the angle $\psi3$. The angle $\psi3$ of the scattering central axis AX**3** is, for example, 10°.

For example, as illustrated in FIG. **5**, the light-scattering layer **24** is an anisotropic scattering layer which relatively strongly scatters a light component incident from the specific direction within a specific angle range $\phi4\pm\alpha4$ in light L**7** incident from a top surface thereof, and relatively weakly scatters other light components (for example, light L**8** in the drawing). The light-scattering layer **24** has a scattering central axis corresponding to a specific angle within the specific angle range $\phi4\pm\alpha4$. For example, as illustrated in FIG. **5**, the light-scattering layer **24** has a scattering central axis AX**4** where scattering of the light L**7** peaks when the light L**7** is incident at an incident angle $\psi4$ from the top surface thereof.

It is to be noted that "scattering of the light L**7** peaks when the light L**7** is incident at an incident angle $\psi4$" means that when the light L**7** is scattered by the light-scattering layer **24** to exit to the bottom surface of the light-scattering layer **24**, the incident angle of the light L**7** where the scattering range of the scattered light is maximized is $\psi4$. Therefore, the scattering central axis AX**4** indicates an axis extending in a direction intersecting with a normal to the light-scattering layer **24** at the angle $\psi4$. The angle $\psi4$ of the scattering central axis AX**4** is, for example, 85°.

The angle $\psi2$ of the scattering central axis AX**2** of the light-scattering layer **22** which is a middle layer in the three light-scattering layers **21** to **23** is larger than the angles $\psi1$ and $\psi3$ of the scattering axes AX**1** and AX**3** of the other light-scattering layers **21** and **23** to widen a viewing angle. Moreover, the angle $\psi3$ of the scattering central axis AX**3** of the light-scattering layer **23** which is an uppermost layer in the three light-scattering layers **21** to **23** is smaller than the angles $\psi1$ and $\psi2$ of the scattering central axes AX**1** and AX**2** of the other light-scattering layers **21** and **22** to enhance luminance in a front direction. The angle $\psi4$ of the scattering central axis AX**4** of the light-scattering layer **24** is larger than the angles $\psi1$ to $\psi3$ of the scattering central axes AX**1** to AX**3** of the three light-scattering layers **21** to **23**.

For example, as illustrated in FIG. **2**, the light-scattering layer **21** includes two kinds of regions with different refractive indices from each other (first regions **21**A and second regions **21**B). Likewise, for example, as illustrated in FIG. **3**, the light-scattering layer **22** includes two kinds of regions with different refractive indices from each other (first regions **22**A and second regions **22**B). For example, as illustrated in FIG. **4**, the light-scattering layer **23** includes two kinds of regions with different refractive indices from each other (first regions **23**A and second regions **23**B). For example, as illustrated in FIG. **5**, the light-scattering layer **24** includes two kinds of regions with different refractive indices from each other (first regions **24**A and second regions **24**B). The light-scattering layers **21** to **24** each may have a louver configuration or a columnar configuration (not illustrated).

The first regions **21**A and the second regions **21**B are formed to extend in a thickness direction of the light-scattering layer **21** and be inclined in a predetermined direction. Likewise, the first regions **22**A and the second regions **22**B are formed to extend in a thickness direction of the light-scattering layer **22** and be inclined in a predetermined direction. The first regions **23**A and the second regions **23**B are formed to extend in a thickness direction of the light-scattering layer **23** and be inclined in a predetermined direction. The first regions **24**A and the second regions **24**B are formed to extend in a thickness direction of the light-scattering layer **24** and be inclined in a predetermined direction. The light-scattering layers **21** to **24** are formed by applying ultraviolet light, from an oblique direction, to a resin sheet made of a mixture of two or more kinds of photopolymerizable monomers or oligomers with different refractive indices from each other, for example. It is to be noted that the light-scattering layers **21** to **24** each may have a configuration different from the above-described configuration, or may be manufactured by a method different from the above-described method. The light-scattering layers **21** to **24** may have configurations which are the same as or different from one another.

FIG. **6** schematically illustrates scattering characteristics of the light-scattering layers **21** to **24**. In FIG. **6**, a first angle range **20**B is an angle range configured of a combination of angle ranges $\phi 1 \pm \alpha 1$, $\phi 2 \pm \alpha 2$, and $\phi 3 \pm \alpha 3$ (not illustrated) of the light-scattering layers **21** to **23**. A scattering central axis AX**4'** is symmetrical to the scattering central axis AX**4** with respect to an incident plane **20**A in a direction of a normal to the incident plane **20**A. The second angle range **20**C corresponds to the angle range $\phi 4 \pm \alpha 4$ of the light-scattering layer **24**. A third angle range **20**D is symmetrical to the angle range $\phi 4 \pm \alpha 4$ of the light-scattering layer **24** with respect to the incident plane **20**A in the direction of the normal to the incident plane **20**A. An overlap angle range **20**E is an angle range where the first angle range **20**B and the third angle range **20**D overlap each other. While the overlap angle range **20**E is a small region in the first angle range **20**B, the overlap angle range **20**E makes up a relatively large proportion of the third angle range **20**D.

In FIG. **6**, the first angle range **20**B and the third angle range **20**D overlap each other in an angle sub-range (the overlap angle range **20**E) not including the scattering central axes AX**1** to AX**3** and AX**4'**. Therefore, the light-scattering layer **24** scatters light incident to a top surface thereof within an angle range to which the overlap angle range **20**E is symmetrical with respect to the incident plane **20**A in the direction of the normal to the incident plane **20**A. Moreover, one or more of the light-scattering layers **21** to **23** scatter light incident to a bottom surface thereof within the overlap angle range **20**E. However, as described above, the overlap angle range **20**E is a small region for the first angle range **20**B. Therefore, when light hardly having a component of the overlap angle range **20**E in the first angle range **20**B (typically environmental light) enters the top surface of the light-scattering layer **24**, the light-scattering layer **24** exerts little effect on the light and allows the light to pass therethrough. Therefore, while the light-scattering layer **24** effectively scatters light from the auxiliary light source **70**, the light-scattering layer **24** exerts little effect on light hardly having the component of the overlap angle range **20**E, such as environmental light.

Drive Circuit 60

Auxiliary Light Source 70

The drive circuit **60** drives respective pixels in the liquid crystal display panel **10** by applying, for example, a voltage based on an image signal to respective pixel electrodes included in the refractive electrode layer **33**. The auxiliary light source **70** is used to compensate for lack of environmental light when illuminance of environmental light is not sufficient (for example, during the night or indoors). The auxiliary light source **70** is disposed in a region not facing the image display surface, and, for example, as illustrated in FIG. **1**, the auxiliary light source **70** is disposed beside the image display surface. The auxiliary light source **70** includes, for example, an LED (Light Emitting Diode) with directivity, and light from the auxiliary light source **70** enters the entire image display surface. The auxiliary light source **70** supplies light to the liquid crystal display panel **10** through the optical laminate **20** including the light-scattering layers **21** to **24**. More specifically, the auxiliary light source **70** is configured to allow light therefrom to mainly enter the light-scattering layer **24** within the second angle range **20**C. In other words, it is not necessary to place the auxiliary light source **70** to allow light therefrom to enter the first angle range **20**B (except for the overlap angle range **20**E) used for image display with use of environmental light.

Here, as the second angle range **20**C is an angle range corresponding to the angle range $\phi 4 \pm \alpha 4$ of the light-scattering layer **24**, the incident angle of the light from the auxiliary light source **70** to the image display surface or the light-scattering layer **24** is also extremely large. Moreover, the incident angle of the light from the auxiliary light source **70** to the light-scattering layer **24** is smaller closer to the auxiliary light source **70** and larger farther from the auxiliary light source **70**. In other words, the incident angle of the light from the auxiliary light source **70** to the light-scattering layer **24** has a relatively large width.

Functions and Effects

Next, referring to FIGS. **7** and **8**, an example of functions and effects of the display **1** according to the embodiment will be described below. FIG. **7** schematically illustrates image display with use of environmental light. FIG. **8** schematically illustrates image display with use of light from the auxiliary light source **70**. It is to be noted that the ¼λ plate **25**, the ½λ plate **26**, and the polarizing plate **27** are not illustrated in FIGS. **7** and **8**.

Image Display with Use of Environmental Light

Environmental light La incident from a specific direction at an angle (for example, at an incident angle of 30°) within a specific range is converted into linearly polarized light by the polarizing plate **27**, and further converted into circularly polarized light by the ½λ plate **26** and the ¼λ plate **25** to reach the liquid crystal display panel **10**. Light incident to a pixel to which a voltage is not applied in the environmental light La having reached the liquid crystal display panel **10** is converted into linearly polarized light by the liquid crystal layer **50** to reach the reflective electrode layer **33**. Light reflected by the reflective electrode layer **33** (reflected light Lb) is converted back into circularly polarized light through a reversed path. The circularly polarized light is converted back into linearly polarized light by the ½λ plate **26** and the ¼λ plate **25**, and passes through the polarizing plate **27**. Therefore, in this case, the pixel is bright. Moreover, light incident to a pixel to which a voltage is applied in the environmental light La having reached the liquid crystal display panel **10** reaches the reflective electrode layer **33** in the form of circularly polarized light, and is reflected by the reflective electrode layer **33** to become circularly polarized light. Although the light is converted back into linearly polarized light by the ½λ plate **26** and the ¼λ plate **25**, the polarization axis of the linearly polarized light is orthogonal to a transmission axis of the polarizing plate **27**. Therefore, the linearly polarized light is absorbed by the polarizing plate **27**. Accordingly, the pixel is dark.

The environmental light La passes through the light-scattering layers **21** to **24**, and then reaches the liquid crystal display panel **10**. However, the scattering intensity of the light-scattering layers **21** to **24** have incident-angle dependence; therefore, the environmental light La is hardly scattered by the light scattering layers **21** to **24** and passes through the light-scattering layers **21** to **24** to reach the liquid crystal display panel **10**. On the other hand, the reflected light Lb passes through the light-scattering layers **21** to **24**, and then exits from the liquid crystal display panel **10**. At this time, as the reflected light Lb enters the bottom surface of the light-scattering layer **21** at, for example, an incident angle of 30°, the reflected light Lb is strongly scattered by the light-scattering layer **21**. As scattered light Lc incident to the bottom surface of the light-scattering layer **22** at a small incident angle (approximately 10°) in light strongly scattered by the light-scattering layer **21** does not enter the scattering range of the light-scattering layer **22**, the scattered light Lc is hardly scattered by the light-scattering layer **22** and passes through the light-scattering layer **22**. On the other hand, scattered light Ld incident to the bottom surface of the light-scattering layer **22** at a large incident angle (approximately 60°) in the light strongly scattered by the light-scattering layer **21** is strongly scattered by the light-scattering layer **22**.

The scattered light Lc hardly scattered by the light-scattering layer **22** and passing through the light-scattering layer **22** enters the bottom surface of the light-scattering layer **23** at a small incident angle (approximately 10°). Therefore, the scattered light Lc is strongly scattered by the light-scattering layer **23**. Light strongly scattered by the light-scattering layer **23** is converted into scattered light Lf toward a front direction to enter the bottom surface of the light-scattering layer **24**. As the scattered light Lf does not enter the scattering range of the light-scattering layer **24**, the scattered light Lf is hardly scattered by the light-scattering layer **24** and passes through the light-scattering layer **24** to exit from the liquid crystal display panel **10**.

On the other hand, scattered light Le strongly scattered by the light-scattering layer **22** and passing through the light-scattering layer **22** enters the bottom surface of the light-scattering layer **23** at a large incident angle (a much larger angle than 10°). As the scattered light Le does not enter the scattering range of the light-scattering layer **23**, the scattered light Le is hardly scattered by the light-scattering layer **23** and passes through the light-scattering layer **23** to enter the bottom surface of the light-scattering layer **24**. As the scattered light Le also does not enter the scattering range of the light-scattering layer **24**, the scattered light Le is hardly scattered by the light-scattering layer **24** and passes through the light-scattering layer **24** to exit from the liquid crystal display panel **10**.

Thus, in the embodiment, while a scattering range for the environmental light (the scattered light Lb) reflected by the liquid crystal display panel **10** to enter from the bottom surface side is allowed to be limited by the light-scattering layer **21**, the scattering range is allowed to be expanded by the light-scattering layers **22** and **23** to be wider than the scattering range of the light-scattering layer **21**, i.e., the lowermost layer. Moreover, variations in intensity at a boundary between high and low scattering intensities are allowed to be reduced. Thus, a visually natural image is allowed to be displayed.

Moreover, in the embodiment, as the angle ψ**3** of the scattering central axis AX**3** of the light-scattering layer **23** is smaller than the angles ψ**1** and ψ**2** of the scattering central axes AX**1** and AX**2** of the light-scattering layers **21** and **22**, a natural image with less image blur is allowed to be displayed. Further, an image with high white luminance is allowed to be displayed.

In addition, in the embodiment, the scattered light Le and the scattered light Lf which are produced from the environmental light La are hardly affected by the light-scattering layer **24**, and are allowed to pass through the light-scattering layer **24**. In other words, the light-scattering layer **24** does not act on image display with use of the environmental light La.

Image Display with Use of Light from Auxiliary Light Source **70**

Next, image display with use of light from the auxiliary light source **70** will be described below. Light (source light Lg) from the auxiliary light source **70** incident from a specific direction at an angle within a specific range (for example, an incident angle of 85°) is converted into linearly polarized light by the polarizing plate **27**, and further converted into circularly polarized light by the ½λ plate **26** and the ¼λ plate **25** to reach the liquid crystal display panel **10**. Light incident to a pixel to which a voltage is not applied in the source light Lg having reached the liquid crystal display panel **10** is converted into linearly polarized light by the liquid crystal layer **50** to reach the reflective electrode layer **33**. Light reflected by the reflective electrode layer **33** (reflected light Lb) is converted back into circularly polarized light through a reversed path. The circularly polarized light is converted back into linearly polarized light by the ½λ plate **26** and the ¼λ plate **25**, and passes through the polarizing plate **27**. Therefore, in this case, the pixel is bright. Moreover, light incident to a pixel to which a voltage is applied in the source light Lg having reached the liquid crystal display panel **10** reaches the reflective electrode layer **33** in the form of circularly polarized light, and is reflected by the reflective electrode layer **33** to become circularly polarized light. Although the light is converted back into linearly polarized light by the ½λ plate **26** and the ¼λ plate **25**, the polarization axis of the linearly polarized light is orthogonal to the transmission axis of the polarizing plate **27**. Therefore, the linearly polarized light is absorbed by the polarizing plate **27**. Accordingly, in this case, the pixel is dark.

The source light Lg mainly enters the light-scattering layer **24** within the second angle range **20**C. Therefore, the source light Lg is strongly scattered by the light-scattering layer **24** and passes through the light-scattering layers **21** to **23** to reach the liquid crystal display panel **10**. Light reflected by the liquid crystal display panel **10** (reflected light Lb) passes through the light-scattering layers **21** to **24**, and then exits from the liquid crystal display panel **10**. At this time, as a part of the reflected light Lb enters the bottom surface of the light-scattering layer **21** at, for example, an incident angle of 30°, the part of the reflected light Lb is strongly scattered by the light-scattering layer **21**. As scattered light Lc incident to the bottom surface of the light-scattering layer **23** at a small incident angle (approximately 10°) in the light strongly scattered by the light-scattering layer **21** does not enter the scattering range of the light-scattering layer **22**, the scattered light Lc is hardly scattered by the light-scattering layer **22** and passes through the light-scattering layer **22**. On the other hand, scattered light Ld incident to the bottom surface of the light-scattering layer **22** at a large incident angle (approximately 60°) in the light strongly scattered by the light-scattering layer **21** is strongly scattered by the light-scattering layer **22**.

The scattered light Lc hardly scattered by the light-scattering layer **22** and passing through the light-scattering layer **22** enters the bottom surface of the light-scattering layer **23** at a small incident angle (approximately 10°). Therefore, the scattered light Lc is strongly scattered by the light-scattering layer **23**. The light strongly scattered by the light-scattering layer **23** is converted into scattered light Lf toward a front direction, and enters the bottom surface of the light-scattering layer **24**. As the scattered light Lf does not enter the scattering range of the light-scattering layer **24**, the scattered light Lf is hardly scattered by the light-scattering layer **24** and passes through the light-scattering layer **24** to exit from the liquid crystal display panel **10**.

On the other hand, scattered light Le strongly scattered by the light-scattering layer **22** and passing through the light-scattering layer **22** enters the bottom surface of the light-scattering layer **23** at a large incident angle (a much larger angle than 10°). As the scattered light Le does not enter the scattering range of the light-scattering layer **23**, the scattered light Le is hardly scattered by the light-scattering layer **23** and passes through the light-scattering layer **23** to enter the bottom surface of the light-scattering layer **24**. As the scattered light Le also does not enter the scattering range of the light-scattering layer **24**, the scattered light Le is hardly scattered by the light-scattering layer **24** and passes through the light-scattering layer **24** to exit from the liquid crystal display panel **10**.

Thus, in the embodiment, the source light Lg incident at a very large angle is scattered by the light-scattering layer **24** to be used for image display. Therefore, viewability in a dark site is allowed to be enhanced. Moreover, in the embodiment, the auxiliary light source **70** is configured to allow light therefrom to mainly enter the light-scattering layer **24** within the second angle range **20**C; therefore, it is not necessary to place the auxiliary light source **70** to allow light therefrom to mainly enter the first angle range **20**B (except for the overlap angle range **20**E). Accordingly, the auxiliary light source **70** is allowed to be placed without being restricted by the first angle range **20**B (except for the overlap angle range **20**E); therefore, flexibility in placement of the auxiliary light source **70** is allowed to be provided. Moreover, in the embodiment, the auxiliary light source **70** is placed in a region not facing the image display surface; therefore, an input interface such as a touch sensor is allowed to be mounted in the display **1**.

2. Modifications

First Modification

In the above-described embodiment, the light-scattering layers **21** to **23** are configured to scatter light when light is emitted therefrom; however, they may be configured to scatter light when light is incident thereto. More specifically, for example, as illustrated in FIGS. **9** to **11**, the light-scattering layers **21** to **23** may strongly scatter a light component incident to the light-scattering layers **21** to **23** within the second angle range **20**C and may weakly scatter a light component incident to the light-scattering layers **21** to **23** within an angle range other than the second angle range **20**C.

As illustrated in FIG. **12** which schematically illustrates scattering characteristics of the light-scattering layers **21** to **24**, also in the modification, the first angle range **20**B and the second angle range **20**C overlap each other in an angle sub-range (the overlap angle range **20**E) not including the scattering central axes AX**1** to AX**3** and AX**4**. Therefore, some of the light-scattering layers **21** to **23**, and the light-scattering layer **24** scatter light incident to the bottom surface within the overlap angle range **20**E. However, as described above, the overlap angle range **20**E is a small region for the first angle range **20**B. Therefore, when light hardly having a component of the overlap angle range **20**E in the first angle range **20**B (typically environmental light) enters the bottom surface of the light-scattering layer **24**, the light-scattering layer **24** has little effect on the light and allows the light to pass therethrough. Therefore, while the light-scattering layer **24** effectively scatters the light from the auxiliary light source **70**, the light-scattering layer **24** exerts little effect on light hardly having the component of the overlap angle range **20**E, such as environmental light.

Second Modification

In the above-described embodiment, for example, as illustrated in FIG. **13**, a single-layer light-scattering layer **61** having both functions of two light-scattering layers **21** and **22** may be included instead of the two light-scattering layers **21** and **22**. At this time, the light-scattering layer **61** has a scattering central axis AX**1** where scattering of incident light peaks when an incident angle of light incident from the bottom surface of the light-scattering layer **21** is $\psi 1$. Moreover, for example, the light-scattering layer **61** also has a scattering central axis AX**2** where scattering of incident light peaks when an incident angle of light incident from the bottom surface of the light-scattering layer **22** is $\psi 2$. In other words, the light-scattering layer **61** has both the scattering central axis AX**1** and the scattering central axis AX**2**. For example, the light-scattering layer **61** includes a bulk-like region and two kinds of rod-like regions. The bulk-like region and the rod-like regions have different refractive indices from each other. One of the two kinds of rod-like regions has a shape corresponding to the scattering central axis AX**1**, and the other has a shape corresponding to the scattering central axis AX**2**. The two kinds of the rod-like regions may have refractive indices which are equal to or different from each other. For example, the light-scattering layer **61** is formed by allowing three kinds of regions to extend in a thickness direction and be inclined in a predetermined direction.

Third Modification

In the above-described embodiment, for example, as illustrated in FIG. **14**, a single-layer light-scattering layer **62** having both functions of the light-scattering layers **23** and **24** may be included instead of the two light-scattering layers **23** and **24**. At this time, for example, the light-scattering layer **62** has the scattering central axis AX**3** where scattering of incident light peaks when an incident angle of light incident from the bottom surface of the light-scattering layer **23** is $\psi 3$. Moreover, for example, the light-scattering layer **62** has the scattering central axis AX**4** where scattering of incident light peaks when an incident angle of light incident from the top surface of the light-scattering layer **24** is $\psi 4$. In other words, the light-scattering layer **62** has both the scattering central axis AX**3** and the scattering central axis AX**4**. For example, the light-scattering layer **62** includes a bulk-like region and two kinds of rod-like regions. The bulk-like region and the rod-like regions have different refractive indices from each other. One of the two kinds of rod-like regions has a shape corresponding to the scattering central axis AX**3**, and the other has a shape corresponding to the scattering central axis AX**4**. The two kinds of the rod-like regions may have refractive indices which are equal to or different from each other. The light-scattering layer **62** is formed by allowing three kinds of regions to extend in a thickness direction and be inclined in a predetermined direction, for example.

Fourth Modification

In the above-described embodiment, for example, as illustrated in FIG. **15**, the light-scattering layer **61** may be included instead of the light-scattering layers **21** and **22**, and the light-scattering layer **62** may be included instead of the light-scattering layers **23** and **24**.

Fifth Modification

In the above-described embodiment, for example, as illustrated in FIG. **16**, two light-scattering layers **22** and **23** may not be included, and only the light-scattering layer **21** may be included as a light-scattering layer for environmental light.

Sixth Modification

In the above-described embodiment, for example, as illustrated in FIG. **17**, the light-scattering layer **24** for auxiliary light source may be disposed on a side closer to the bottom surfaces of the light-scattering layers **21** to **23** for environmental light. However, in such a case, the light-scattering layer **24** is preferably configured to scatter light when the light exits therefrom. For example, as illustrated in FIG. **18**, the light-scattering layer **24** may relatively strongly scatter a light component incident to the light-scattering layer **24** within the second angle range **20**C in light incident from the liquid crystal display panel **10**, and may relatively weakly scatter a light component incident within an angle range other than the second angle range **20**C.

In the present modification, as illustrated in FIGS. **2** to **4**, the light-scattering layers **21** to **23** may be configured to scatter light when the light exits therefrom. In this case, as illustrated in FIG. **19** which schematically illustrates scattering characteristics of the light-scattering layers **21** to **24**, the first angle range **20**B and the second angle range **20**C overlap each other in an angle sub-range (the overlap angle range **20**E) not including the scattering central axes AX**1** to AX**3** and AX**4**. Therefore, while the light-scattering layer **24** effectively scatters light from the auxiliary light source **70**, the light-scattering layer **24** exerts little effect on light hardly having a component of the overlap angle range **20**E such as environmental light.

Moreover, in the present modification, as illustrated in FIGS. **9** to **11**, the light-scattering layers **21** to **23** may be configured to scatter light when light is incident thereto. In this case, as illustrated in FIG. **20** which schematically illustrates scattering characteristics of the light-scattering layers **21** to **24**, the first angle range **20**B and the third angle range **20**D also overlap each other in an angle sub-range (the overlap angle range **20**E) not including the scattering central axes AX**1** to AX**3** and AX**4**. Therefore, while the light-scattering layer **24** effectively scatters light from the auxiliary light source **70**, the light-scattering layer **24** exerts little effect on light hardly having a component of the overlap angle range **20**E such as environmental light.

3. Application Example

Next, an application example of the display **1** according to any of the above-described embodiment and modifications thereof will be described below. FIG. **21** is a perspective view illustrating an example of a schematic configuration of an electronic unit **100** according to the application example. The electronic unit **100** is a cellular phone, and, for example, as illustrated in FIG. **21**, the electronic unit **100** includes a main body section **111**, and a display body section **112** openable and closable with respect to the main body section **111**. The main body section **111** includes operation buttons **115** and a transmitter section **116**. The display body section **112** includes a display **113** and a receiver section **117**. The display **113** displays various indications for telephone communication on a display screen **114** thereof. The electronic unit **100** includes a control section (not illustrated) to control the operation of the display **113**. For example, the control section outputs an image signal to the display **113**. The control section is disposed in the main body section **111** or the display body section **112** as a part of a control section controlling the entire electronic unit **100** or a control section different from the control section controlling the entire electronic unit **100**.

The display **113** has the same configuration as that of the display **1** according to any of the above-described embodiment and modifications thereof. Therefore, as flexibility in placement of the auxiliary light source **70** is allowed to be provided in the display **113**, the electronic unit **100** also has flexibility in design. Moreover, in the electronic unit **100**, an input interface such as a touch sensor is allowed to be mounted in the display **1**. Further, as the display **1** is used as the display **113**, a visually natural image is allowed to be displayed. In the case where, as the display **113**, the display **1** in which the angle ψ**2** of the scattering central axis AX**2** of the light-scattering layer **22** which is smaller than the angles ψ**1** and ψ**3** of the scattering central axes AX**1** and AX**3** of the light-scattering layers **21** and **23** is used, a natural image with less image blur is allowed to be displayed. In addition, an image with high white luminance is allowed to be displayed.

It is to be noted that, in addition to the above-described cellular phone, electronic units to which the display **1** according to any of the above-described embodiment and modifications thereof is applicable include a personal computer, a liquid crystal television, a viewfinder type or monitor direct-view type videotape recorder, a car navigation system, a pager, an electronic organizer, an electronic calculator, a word processor, a work station, a videophone, a POS terminal, and the like.

Moreover, the technology is allowed to have the following configurations.

(1) A display including:

a reflective or semi-transmissive display panel;

a light-scattering layer disposed on a top surface of the display panel; and

an auxiliary light source supplying light to the display panel through the light-scattering layer,

in which the light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges,

the light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range, the first angle range and a third angle range which is an incident-plane symmetrical angle range symmetrical to the second angle range overlap each other in an angle sub-range not including the first specific angle and an incident-plane symmetrical angle symmetrical to the second specific angle, and

the auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

(2) The display according to (1), in which

the incident-plane symmetrical angle symmetrical to the second specific angle is larger than the first specific angle.

(3) The display according to (1) or (2), in which

the light-scattering layer includes

a first anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within the first angle range and relatively weakly scatters light incident within an angle range other than the first angle range, and

a second anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within the second angle range and relatively weakly scatters light incident within an angle range other than the second angle range.

(4) The display according to (3), in which

the second anisotropic front scattering layer is disposed on a top side of the first anisotropic front scattering layer, and

the auxiliary light source is configured to allow light therefrom incident from the side closer to the auxiliary light source to mainly enter the light-scattering layer within the second angle range.

(5) The display according to (3), in which

the second anisotropic front scattering layer is disposed on a bottom side of the first anisotropic front scattering layer, and

the auxiliary light source is configured to allow light therefrom reflected by the display panel to be incident from the side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

(6) The display according to (3), in which

the first anisotropic front scattering layer is configured of one or a plurality of anisotropic front scattering layers each having a single scattering central axis.

(7) The display according to (3), in which

the first anisotropic front scattering layer includes

a third anisotropic front scattering layer having a plurality of scattering central axes as the first scattering central axis, and

a fourth anisotropic front scattering layer having a single scattering central axis as the first scattering central axis.

(8) The display according to (1) or (2), in which

the light-scattering layer is a single-layer anisotropic front scattering layer.

(9) The display according to any one of (1) to (8), in which

the light-scattering layer relatively strongly scatters a light component incident to the light-scattering layer within the second angle range in light incident from the side closer to the display panel and relatively weakly scatters a light component incident within an angle range other than the second angle range, and relatively strongly scatters a light component incident to the light-scattering layer within the first angle range in light incident from a side opposite to the display panel and relatively weakly scatters a light component incident within an angle range other than the first angle range.

(10) The display according to any one of (1) to (8), in which

the light-scattering layer relatively strongly scatters a light component incident to the light-scattering layer within the first angle range in light incident from the side closer to the display panel and relatively weakly scatters a light component incident within an angle range other than the first angle range, and relatively strongly scatters a light component incident to the light-scattering layer within the first angle range in light incident from a side opposite to the display panel and relatively weakly scatters a light component incident within an angle range other than the first angle range.

(11) A display including:

a reflective or semi-transmissive display panel;

a light-scattering layer disposed on a top surface of the display panel; and

an auxiliary light source supplying light to the display panel through the light-scattering layer,

in which the light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges,

the light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range,

the first angle range and the second angle range overlap each other in an angle sub-range not including the first specific angle and the second specific angle, and

the auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

(12) An electronic unit including a display, the display including:

a reflective or semi-transmissive display panel;

a light-scattering layer disposed on a top surface of the display panel; and

an auxiliary light source supplying light to the display panel through the light-scattering layer,

in which the light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges,

the light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range,

the first angle range and a third angle range which is an incident-plane symmetrical angle range symmetrical to the second angle range overlap each other in an angle sub-range not including the first specific angle and an incident-plane symmetrical angle symmetrical to the second specific angle, and

the auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

(13) An electronic unit including a display, the display including:

a reflective or semi-transmissive display panel;

a light-scattering layer disposed on a top surface of the display panel; and an auxiliary light source supplying light to the display panel through the light-scattering layer,

in which the light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges,

the light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range,

the first angle range and the second angle range overlap each other in an angle sub-range not including the first specific angle and the second specific angle, and

the auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

The present application contains subject matter related to that disclosed in Japanese Priority Patent Application 2011-177827 filed in the Japan Patent Office on Aug. 16, 2011, the entire content of which is hereby incorporated by reference.

It should be understood by those skilled in the art that various modifications, combinations, sub-combinations, and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. A display comprising:

a reflective or semi-transmissive display panel;

a light-scattering layer disposed on a top surface of the display panel; and

an auxiliary light source supplying light to the display panel through the light-scattering layer,

wherein the light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges,

the light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range,

the first angle range and a third angle range which is an incident-plane symmetrical angle range symmetrical to the second angle range overlap each other in an angle sub-range not including the first specific angle and an incident-plane symmetrical angle symmetrical to the second specific angle, and

the auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

2. The display according to claim **1**, wherein

the incident-plane symmetrical angle symmetrical to the second specific angle is larger than the first specific angle.

3. The display according to claim **1**, wherein

the light-scattering layer includes

a first anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within the first angle range and relatively weakly scatters light incident within an angle range other than the first angle range, and

a second anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within the second angle range and relatively weakly scatters light incident within an angle range other than the second angle range.

4. The display according to claim **3**, wherein

the second anisotropic front scattering layer is disposed on a top side of the first anisotropic front scattering layer, and

the auxiliary light source is configured to allow light therefrom incident from the side closer to the auxiliary light source to mainly enter the light-scattering layer within the second angle range.

5. The display according to claim **3**, wherein

the second anisotropic front scattering layer is disposed on a bottom side of the first anisotropic front scattering layer, and

the auxiliary light source is configured to allow light therefrom reflected by the display panel to be incident from the side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

6. The display according to claim **3**, wherein

the first anisotropic front scattering layer is configured of one or a plurality of anisotropic front scattering layers each having a single scattering central axis.

7. The display according to claim **3**, wherein

the first anisotropic front scattering layer includes

a third anisotropic front scattering layer having a plurality of scattering central axes as the first scattering central axis, and

a fourth anisotropic front scattering layer having a single scattering central axis as the first scattering central axis.

8. The display according to claim **1**, wherein

the light-scattering layer is a single-layer anisotropic front scattering layer.

9. The display according to claim **1**, wherein

the light-scattering layer relatively strongly scatters a light component incident to the light-scattering layer within the second angle range in light incident from the side closer to the display panel and relatively weakly scatters a light component incident within an angle range other than the second angle range, and relatively strongly scatters a light component incident to the light-scattering layer within the first angle range in light incident from a side opposite to the display panel and relatively weakly scatters a light component incident within an angle range other than the first angle range.

10. The display according to claim **1**, wherein

the light-scattering layer relatively strongly scatters a light component incident to the light-scattering layer within the first angle range in light incident from the side closer to the display panel and relatively weakly scatters a light component incident within an angle range other than the first angle range, and relatively strongly scatters a light component incident to the light-scattering layer within the first angle range in light incident from a side opposite to the display panel and relatively weakly scatters a light component incident within an angle range other than the first angle range.

11. A display comprising:

a reflective or semi-transmissive display panel;

a light-scattering layer disposed on a top surface of the display panel; and an auxiliary light source supplying light to the display panel through the light-scattering layer,

wherein the light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges,

the light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range,

the first angle range and the second angle range overlap each other in an angle sub-range not including the first specific angle and the second specific angle, and

the auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

12. An electronic unit including a display, the display comprising:

a reflective or semi-transmissive display panel;

a light-scattering layer disposed on a top surface of the display panel; and

an auxiliary light source supplying light to the display panel through the light-scattering layer,

wherein the light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges,

the light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range,

the first angle range and a third angle range which is an incident-plane symmetrical angle range symmetrical to the second angle range overlap each other in an angle sub-range not including the first specific angle and an incident-plane symmetrical angle symmetrical to the second specific angle, and

the auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

13. An electronic unit including a display, the display comprising:

a reflective or semi-transmissive display panel;

a light-scattering layer disposed on a top surface of the display panel; and

an auxiliary light source supplying light to the display panel through the light-scattering layer,

wherein the light-scattering layer is an anisotropic front scattering layer which relatively strongly scatters light incident from a specific direction within a first angle range and a second angle range and relatively weakly scatters light incident within an angle range other than the first and second angle ranges,

the light-scattering layer has a first scattering central axis corresponding to a first specific angle in the first angle range and a second scattering central axis corresponding to a second specific angle in the second angle range,

the first angle range and the second angle range overlap each other in an angle sub-range not including the first specific angle and the second specific angle, and

the auxiliary light source is configured to allow light therefrom incident from a side closer to the auxiliary light source or light therefrom reflected by the display panel to be incident from a side closer to the display panel to mainly enter the light-scattering layer within the second angle range.

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